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UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE H. H. BENNETT, CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL REGIONAL CONSERVATOR

RECONNAISSANCE INVESTIGATION OF SEDIMENTATION IN POSSUM KINGDOM LAKE

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Fort Worth, Texas
December 1949
SCS-TP-87

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Frontispiece

"Hell's Gate" and precipitous bluffs near Possum Kingdom Dam

Reconnaissance Investigation of Sedimentation in Possum Kingdom Lake

Introduction

Possum Kingdom Lake has been officially named "Morris Sheppard Lake" and is listed by that name on many maps and records. However it was first called "Possum Kingdom," and is best known by this name, so it will be referred to as Possum Kingdom Lake in this report. It was constructed by the Brazos River Conservation and Reclamation District, an agency of the State of Texas first created in 1929, with the permanent organization perfected in 1935. Plans and preliminary surveys have been made by the District for a number of large dams on the Brazos River and its major tributaries. Possum Kingdom dam, completed in July 1941, is the only major development completed by the District to date. The District is also cooperating with cities in the western part of the watershed in the construction of small reservoirs on tributary streams and several of these small lakes have been completed.

Possum Kingdom Lake is a multiple purpose reservoir. It creates hydro-electric power by means of a power plant constructed directly below the dam. It also provides some flood control protection for downstream bottomland, and water for irrigation use in the Gulf Coastal Plains area is released from it when the normal flow of the Brazos River is insufficient to meet irrigation needs. The lake is used extensively for recreation and fishing.

A reconnaissance investigation of the sediment deposits in the lake was made February 10 to 24, 1949 as a part of the United States Department of Agriculture Flood Control Survey of the Brazos River Watershed. Additional measurements were taken in the upper part of the lake on June 22, 1949. The survey party consisted of 4 employees of the Soil Conservation Service Regional Office, Fort Worth, Texas, and Mr. Jack Smith of the Brazos River Conservation and Reclamation District, Mineral Wells, Texas.

Description of the Dam and Reservoir

Location. Possum Kingdom dam extends in a general north-south direction across the Brazos River in Palo Pinto County, Texas at approximately 32° 52' N latitude and 98° 26' W longitude. It is about 13 miles southwest from Graford and 20 miles northwest of Mineral Wells. The major portion of the lake lies in Palo Pinto County. A large arm of the lake extends west into Stephens County and the long tortuous upper end of the lake extends northwesterly into Young County for a distance of 35 river miles.

Costs. The costs of the Possum Kingdom dam and reservoir project, as shown in the Brazos River Conservation and Reclamation District

records are as follows:

Land and land rights.....	$1,137,819
Structures and improvements.....	476,326
Reservoir dam and waterways.....	6,188,088
Waterwheels, turbines and generators	668,990
Accessory electrical equipment....	128,690
Miscellaneous power equipment.....	54,793
Total	$8,654,706

Dam and Spillway. The dam is an earth fill dike with concrete core wall on the south and a reinforced concrete spillway and bulkhead, Ambursen hollow massive buttress type, on the north. The earth fill section is 1147 feet long, 21 feet wide at the top, with a maximum base width of 200 feet at its north end where it joins the concrete bulkhead section. The slopes are 3:1 upstream and 2:1 downstream. The concrete bulkhead dam and spillway section is 1600 feet in length. The top of the dam is at elevation 1024 feet above mean sea level, the river bed elevation is 855 feet, and spillway (top of crest gates closed) elevation is 1000 feet. The north end of the dam ties into a vertical rock bluff which rises 200 feet above the valley floor. The bulkhead portion of the dam is reinforced concrete on the upstream side, supported by massive tapering reinforced concrete buttresses on the downstream side. The concrete face curves upward at a variable pitch with an average slope of about 8:10. A picture of the spillway and north end of the dam is shown in Figure 1.

The spillway section extends across the old river bed area. It has a total effective length of 663 feet and a maximum capacity of 450,000 c.f.s. The spillway consists of 9 crest gates, modified bear trap type, operated independently by hydraulic means. Each crest gate is 73 feet, 8 inches long and 13 feet high, with reinforced concrete piers at each end. Long concrete wing walls at the ends of the spillway section protect the dam and power house. The spillway below the metal crest gates is reinforced concrete on the upstream and downstream faces, with a variable curved shape, and an average slope of 8:10. The spillway is hollow on the inside, with concrete piers for support. A catwalk traverses its length to permit inspection, and provide access to the controls of a high pressure outlet gate located near the north end of the spillway. This outlet is 54 inches in diameter and has an electrically operated control gate. Its centerline elevation is 877 feet, and the capacity is 1170 c.f.s. at 123 feet head. Additional outlets at elevation 910 feet are provided by two steel penstocks to the powerhouse. Each penstock is 12 feet in diameter and carries 1335 c.f.s. under full plant operation.

The powerhouse is a modern concrete building located immediately downstream from the reinforced concrete portion of the dam on the left (north) bank of the Brazos River (see Fig. 2). Access from the top of the bluff at the north end of the dam to the powerhouse and top of the dam is provided by an automatic elevator system. A vehicular service road to the power plant has also been provided. The power plant installations include two single runner vertical type hydraulic turbines each developing 17,000 h.p. at 171.4 revolutions per minute. The operating

Figure 1. Portion of Possum Kingdom Dam and Spillway.

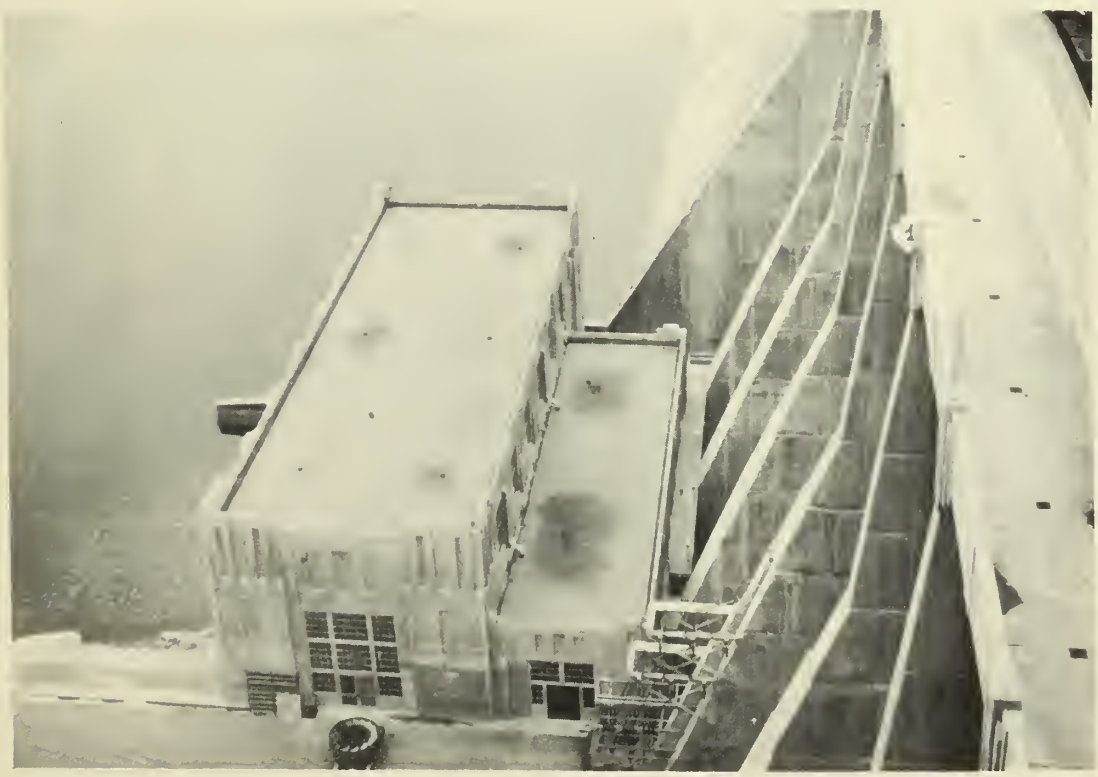

Figure 2. Power plant and concrete buttresses of bulkhead section, Possum Kingdom Dam.

head of the turbines is 124.5 feet under full reservoir. There are two electrical generators, vertical shaft, unbrella type, each having a rated capacity of 12,500 KVA. A third generating unit of similar size can be installed in the power house should the need arise.

The lake is comparatively narrow for most of its length, averaging about 2500 feet wide in the lower portion. It is 65 river miles long but only 35 miles in length by airline, with a shoreline length of 310 miles (Fig. 6). It is confined for about 75 percent of its length by steep hills and bluffs rising from 50 feet to 150 feet above the water (see frontispiece).

The main body of the lake follows a winding course, and has numerous large bends, some of them doubling back until they nearly converge. There are several islands in the lake, the principal ones being Costello, Carter, and Sand Islands. The principal tributary arms to the lake are formed by Caddo, Cedar, and Rock Creeks.

Water Level. Original plans for operation of the lake were to maintain the water level as near to spillway elevation as inflow and use permitted. After a year or more of operation in this manner it was decided to maintain the lake several feet below spillway level in order to give more flood control protection to downstream areas, and this policy is being followed at present. The average lake level since 1945 has been about 10 feet below spillway. The lowest stage of the lake since storage began in May, 1941 occurred in January, 1944, when it was 22.4 feet below spillway. A monthly record of the lake stages to February 1949, prepared by the Brazos River Conservation and Reclamation District, is shown graphically in Figure 3. This graph also shows the dates when water was released through the spillway gates. The maximum recorded flow through the spillway in any one day was 78,000 acre-feet. Complete records of flow through the spillway and the power penstocks are available at the office of the Brazos River Conservation and Reclamation District, Mineral Wells, Texas. Maps of the lake and detailed plans of the dam, spillway, and powerhouse are also on file in their office.

The Drainage Area

Hydrologic Information. The watershed of the lake lies within a sub-humid region, the average annual rainfall in the contributing area since 1900 being about 24 inches. The rate which increases rather uniformly from west to east, ranges from about 19 inches annually near the Texas-New Mexico border to 29 inches at the dam. Average rainfall since the lake has been in operation closely approaches the long time average. In 1941 however, the year the dam was completed, rainfall was 20 inches over normal. As a result the lake filled in ten days instead of in several years as was anticipated.

Water flow in the Brazos River at South Bend, just above Possum Kingdom Lake, has varied from a high of 2,402,000 acre-feet for the water year 1940-41 to 171,400 acre-feet for the water year 1943-44. The maximum recorded monthly discharge, 1,238,000 acre-feet, occurred in May 1941 when the lake first filled. This amount is about 50 percent

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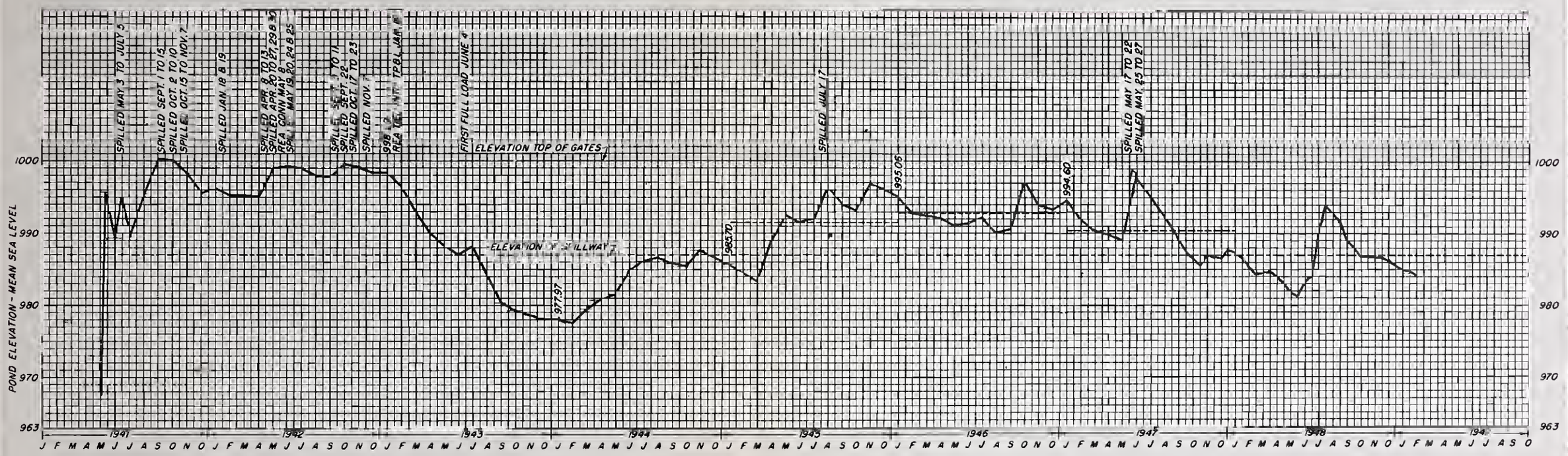
Figure 3

ELEVATIONS OF WATER SURFACE ON POSSUM KINGDOM LAKE


POND ELEVATION - MEAN SEA LEVEL
1000
990
980
970
963
SPILLED MAY 3 TO JULY 5
SPILLED SEPT. 1 TO 15
SPILLED OCT. 2 TO 10
SPILLED OCT. 15 TO NOV. 7
SPILLED JAN. 18 & 19
SPILLED APR. 8 TO 13
SPILLED APR. 20 TO 27, 29 & 30
REA CONN MAY 8, 11, 20, 24 & 25
SPILLED MAY 19
SPILLED SEPT. 1 TO 11
SPILLED SEPT. 22
SPILLED OCT. 17 TO 23
SPILLED NOV. 3
998.12
REA CO. INT. TO 8:00 A.M. JAN. 8
FIRST FULL LOAD JUNE 4
ELEVATION TOP OF GATES
ELEVATION SPILLWAY
977.97
985.70
SPILLED JULY 17
995.06
994.60
SPILLED MAY 17 TO 22
SPILLED MAY 25 TO 27
1941
1942
1943
1944
1945
1946
1947
1948
J F M A M J J A S O N O J F M A M J J A S O N O J F M A M J J A S O N O J F M A M J J A S O N O J F M A M J J A S O N O J F M A M J J A S O N O J F M A M J J A S O

REFERENCE: Reproduced from graph constructed by the Brazos River Conservation and Reclamation District

greater than the original storage capacity of the lake. The average annual flow from October 1940 to September 1947 has been 873,900 acre-feet at South Bend. An additional amount of water flows directly into the lake from tributaries, principally Caddo, Cedar, Rock, and Salt Creeks which is not measured, hence the total flow into the lake is estimated to be about 900,000 acre-feet annually.

Physiography and Geology. The Brazos River and its tributaries above Possum Kingdom dam drain an area of 23,016 square miles (Fig. 4), not including the surface area of the lake. About 8,950 square miles (39 percent) of the drainage area in the High Plains at the upper end of the basin, however, contributes only insignificant amounts of water or sediment to downstream localities. The drainage area is nearly 250 miles long and has a maximum width of about 100 miles. For calculations of sediment contribution rates in this report the figure 14,066 square miles is used for the area of direct drainage contributing to Possum Kingdom Lake. Of this contributing area, however, about 1111 square miles lie upstream from 21 smaller reservoirs. Table 1 shows the known reservoirs, their locations, and pertinent information on sedimentation.

Great variety of geology and physiography characterizes the upper Brazos River Basin. Its topographies range from high, flat, youthful uplands to rough mountainous areas. Parts of two major physiographic divisions, the Great Plains and the Central Lowland, are represented in the drainage area of Possum Kingdom Reservoir. In general the belts of outcrop of the various rock formations extend transversely across the main drainage lines. Formations ranging in age from Pennsylvanian to Recent are represented (see Geologic-Physiographic Map, Fig. 5).

The High Plains Section of the Great Plains Province covers all or parts of 13 counties in Texas and 2 counties in New Mexico, all at the upper end of the Brazos River drainage. It is a nearly flat upland plain lying at elevations ranging from 4500 feet above sea level in the western part to approximately 3000 feet east of Lubbock. Local relief rarely exceeds 20 feet within one mile except in the immediate vicinity of the major valleys such as White River and Double Mountain Fork. The smooth surface of the plain is featured by hundreds of small, shallow lakes which have more or less water at various times depending upon rainfall. Most of the area has virtually no surface drainage, hence much rainfall seeps directly into underlying formations and does not contribute to stream run-off.

The High Plains were formed during Pliocene time by many relatively large streams which developed a great alluvial plain eastward from the Rocky Mountains. This deposit is called the Ogalalla formation (see Fig. 5). It consists of irregularly stratified, chiefly unconsolidated materials ranging from clay and silt to coarse gravel. Its thickness ranges from 100 feet or less to 500 feet. In places it has zones of very strongly-cemently sandstone and contains lenticular deposits of loose sands and gravels. Consequently it has relatively high porosity and permeability and forms a valuable ground water producer. At its base in most places occurs a well cemented zone which is resistant to erosion and in places forms a part of the familiarly known "cap-rock" of the area. Its eastern fringe forms a prominent

Table 1 - Smaller Reservoirs in the Drainage Area of Possum Kingdom Lake

Name	Location (nearest city)	Stream	Ownership and Purpose of Reservoir 1/	Date Completed	Original Capacity (Ac-Ft)	Annual Depletion of Storage (Percent)	Drainage Area (Sq. Mi.)	Annual Sediment Accumulation Per Sq. Mi. of Drainage (Ac-Ft)
Lake Fort Phantom Hill	Abilene (12 mi. NE)	Elm Cr.	City of Abilene, MWS	1939	70,000		482	
Lake Cisco	Cisco (4 mi. N)	Sandy Cr.	City of Cisco, MWS	1923	31,250		23	
Buffalo Lake No. 1	Lubbock (9 mi. SE)	Double Mt. Fk.	W. H. Rodgers, R	1937	280		90	
Buffalo Lake No. 2	Lubbock (9 mi. SE)	Double Mt. Fk.	W. H. Rodgers, R	1938			90 2/	
Two Draw Lake	Post (1 mi. N)	Rattlesnake Cr.	Double U Co. R	1910			3	
Lake Trammel	Sweetwater (6 mi. S)	Sweetwater Cr.	City of Sweetwater, MWS	1916	3,161	0.5	55	0.26
Lake Sweetwater	Sweetwater (7 mi. SE)	Bitter Cr.	City of Sweetwater, MWS	1930	13,810	0.3	110	0.4
Railroad Lake	Sweetwater	Kildoogan Cr.	G.C. & S.F. Ry I	1910	890		51	
Lake Abilene	Abilene (19 mi. SW)	Elm Cr.	City of Abilene, MWS	1921	10,325	0.19	98 2/	0.21
Upper Lake	Hamlin (2 mi. W)	California Cr.	City of Hamlin, MWS	1917	510	0.9	32 2/	0.15
Moore Lake	Hamlin (2 mi. W)	California Cr.	City of Hamlin, MWS	1909			32	
New Hamlin Res.	Hamlin (4 mi. S)	Dry Calif. Cr.	City of Hamlin, MWS	1939	2,460		36	
Lake Penick	Leuders	Clear Fork	City of Stamford, MWS	1920	3,096	4.5	2250 3/	0.06
Anson City Res.	Anson (4 mi. E)	Redmud Cr.	City of Anson, MWS	1941	1,250		36	
Lake Lytle	Abilene (1 mi. SE)	Lytle Cr.	West Texas Utilities, I	1909			64 2/	
Lake Kirby	Abilene (3 mi. S)	Cedar Cr.	City of Abilene, MWS	1928	8,133	0.5	44 2/	0.94
Lake Diller	Albany	N. Hubbard Cr.	City of Albany, MWS	1913	400	0.3	8	0.18
Delafosse Lake	Albany (12 mi. E)	Dry Branch	George Delafosse, I	1918			11	
Throckmorton City Res.	Throckmorton (1 mi. W)	-	City of Throckmorton, MWS	1941	1,650		10	
Tucker Lake	Strawn (5 mi. W)	Russell Cr.	City of Strawn, MWS	1937	1,600		5	
Lake Daniel	Breckenridge (7 mi. S)	Gonzales Cr.	City of Breckenridge, MWS	1939	10,000		115	
Lake Hagaman	Ranger (2 mi. NE)	N. Palo Pinto Cr.	Hagaman Estate, MWS	1913	1,158		2	
Lake Eddleman	Graham (2 mi. N)	Flint Cr.	City of Graham, MWS	1929	6,500	0.5	42	0.82
						Total	1111	

1/ MWS - Municipal Water Supply
I - Industrial
R - Recreation

2/ Included in drainage area of another reservoir downstream.

3/ Most sediment by-passes the dam.

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Soil Conservation Service
Western Gulf Region
December 1949 - RER

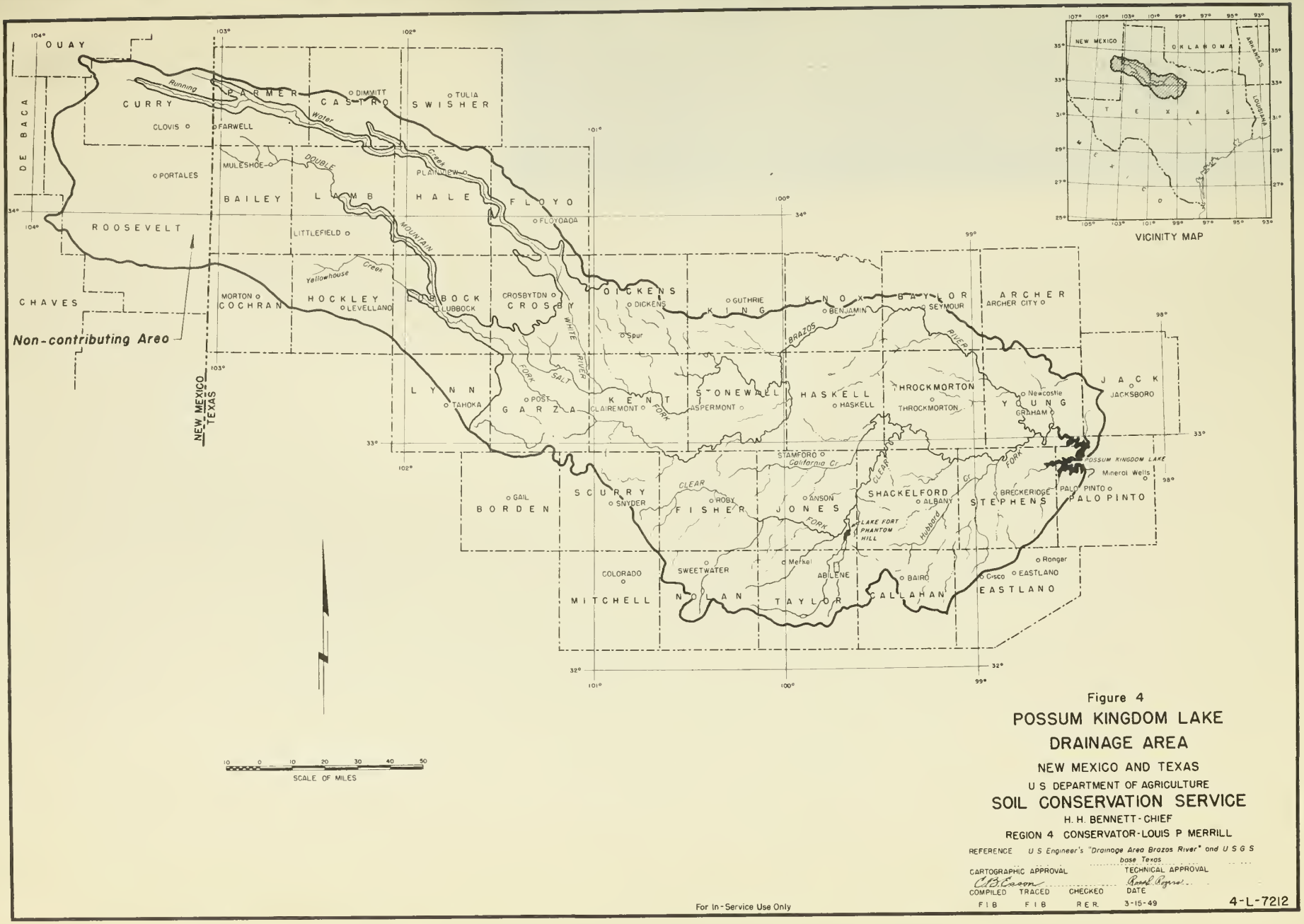

Figure 4

POSSUM KINGDOM LAKE DRAINAGE AREA

NEW MEXICO AND TEXAS

U S DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

H. H. BENNETT - CHIEF

REGION 4 CONSERVATOR-LOUIS P MERRILL

REFERENCE U S Engineer's "Drainage Area Brazos River" and U S G S base Texas

CARTOGRAPHIC APPROVAL C.B. Eason

TECHNICAL APPROVAL Roark Rogers

COMPILED	TRACED	CHECKED	DATE
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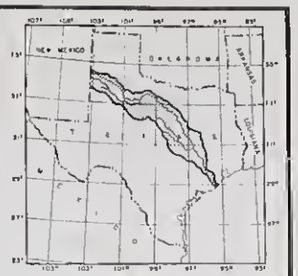

Non-contributing Area

Redbeds Plains

Central Lowland

Polo Pinto Section

West Cross Timbers

Grand Prairie

East Cross Timbers

Edwards Plateau and Lampasas Cut Plain and Outliers of Edwards on Pennsylvanian rocks.

Black Prairie

Fayette Coastal Plain

West Gulf Coastal Plain

Coastal Prairie

GULF OF MEXICO

LEGEND

QUATERNARY	Pleistocene and Recent	Q	Alluvium, beach sand, and terrace deposits.
		Osd	Sand dunes
	Pleistocene	Qb	Beaumont clay
		Ql	Lissie formation
TERTIARY	Pliocene	Pa	Ogallala formation
		Pw	Willis sand
	Miocene	Ml	Logarto clay
		Mo	Oakville and Catahoula
	Eocene	Ej	Jackson-undifferentiated
		Ecl	Claiborne-undifferentiated
		Ewi	Wilcox group
		Emi	Midway group
CRETACEOUS	Upper Cretaceous Gulf Series	Kn	Navarro group-undifferentiated
		Kta	Taylor group
		Kwc	Wolfe City sand
		Ka	Austin chalk
		Kef	Eagle Ford group
		Kwb	Woodbine sand
	Lower Cretaceous (Comanche)	Kwf	Washita and Fredericksburg groups
		Kt	Trinity group
TRIASSIC		Trd	Dockum group
PERMIAN		Cp	Double Mountain, Clear Fork, and Wichita groups
PENNSYLVANIAN		Cpe	Cisco, Canyon, and Strawn group

SCALE OF MILES

Base map compiled from U.S. Engineers' Drainage Area Brazos River and U. S. G. S. Base of Texas.

Figure 5

GENERALIZED GEOLOGIC PHYSIOGRAPHIC MAP

BRAZOS RIVER WATERSHED - TEXAS

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REFERENCE: Maps and Publications of U. S. Geological Survey, and Texas Bur. of Econ. Geol. and Physiography of U.S., Fenneman

CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

COMPILED	TRACED	CHECKED	DATE	
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F.I.R. APRIL 1949 Base 4-R-7245

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escarpment which is deeply eroded by the major streams which have formed canyons, peculiarly shaped erosional remnants, and numerous outliers.

The Edwards Plateau Section of the Great Plains is represented by outliers and rims occurring along the south border of the basin from Nolan County to Travis County in the lower Brazos River area. It is composed chiefly of resistant limestone formations overlain by thin soils, and its average rates of erosion and sediment output are low. The main plateau, which is well developed in the Colorado River area, is not present in any large area in the Brazos River drainage. One prominent occurrence is an outlier extending roughly east and west through Nolan, Taylor and Callahan counties, and is commonly called the Callahan Divide. It is a series of large flat-topped mesas underlain by predominantly limestone formations of Lower Cretaceous Age (see Fig. 5).

The Redbeds Plains Section of the Central Lowland Province occupies about 45 percent of the upper Brazos River drainage area. It occupies a roughly rectanglular area from Crosby and Garza counties to Throckmorton and Shackelford counties in the east. It has well-drained rolling topography in which stream gradients are relatively high. The bluffs along Salt Fork, Double Mountain Fork and Clear Fork range from 100 to 200 feet in height and even the bedrock of the valley walls is subject to considerable lateral erosion by the main streams. Two systems of rock formations underlie the area. Along the west margin of the Redbeds section in Crosby, Garza, and Dickens counties the chief country rock is the Dockum formation of Triassic age. The remainder of the section is underlain by Permian formations. Most of the formations are dominantly reddish in color and consist chiefly of silts and sands with some moderately cemented sandstones and much gypsum. Limestones, although subordinate, are locally conspicuous. The land surface is interruped by numerous outliers of younger formations such as the Ogalalla and later dune sand and some mesas of Cretaceous rocks. In general the Redbeds Plains are subject to serious accelerated erosion, especially gully development, and they are poor sources of ground water.

The Palo Pinto section of the Central Lowland Province extends southeasterly across the drainage area in a belt about 60 miles wide from Young and Jack counties to Eastland and Callahan counties (see Fig. 5). The dam and reservoir are situated entirely within the Palo Pinto section. It is an area of ridged topography with relatively high relief and many scenic features. The bluffs around Possum Kingdom Reservoir range from 200 to 400 feet in height (see frontispiece). The Brazos River Valley has entrenched meanders through much of this section resembling some Appalachian Mountain valleys. Tributary valleys have steep gradients, and their courses are controlled by rock structure.

The main ridges are capped by resistant sandstones and limestones, and the tributary valleys have been developed in shales. Rates of erosion are relatively low, with local exceptions in areas of softer sandstones and shales. Three series of rocks of Pennsylvanian age, Strawn, Canyon, and Cisco, underlie the Palo Pinto Section, and some bituminous coal is produced from the lower beds in local mines. This section corresponds roughly to the Reddish Prairies of the soils survey classification.

Land Use. Table 2 shows the proportionate areas of the watershed devoted to different types of land use by physiographic subdivision.

Table 2 - Land Use in the Drainage Area of Possum Kingdom Lake by Physiographic Subdivisions

Physiographic Section	Area	Cultivated	Grassland	Pastured Woodland	Miscellaneous
	Sq. mi.	Percent	Percent	Percent	Percent
High Plains					
Contributing	496				
Non-contributing	8,950				
Total	9,446	87.0	11.5	-	1.5
Edwards Plateau	627	7.0	91.5	-	1.5
Redbed Plains	8,522	39.0	59.0	-	2.0
Palo Pinto	4,421	25.0	67.0	7.0	1.0

Investigation of Sediment Deposits

Survey Methods. Measurements of sediment were made with the spud, or sediment measuring bar, attached to a rope. Water depths were determined at each sediment measurement by means of a bell-shaped cast aluminum sounding weight fastened to a marked copper-cored sounding line. Survey procedure was in accordance with standard reconnaissance methods developed by the Soil Conservation Service.1,2/ Thirty-three approximate ranges or cross-sections were run on which a total of 234 sediment and water measurements were made. The ends of the ranges were identified on a shoreline map of the reservoir and surrounding area, scale 1 inch equals 4000 feet, which was prepared by the Brazos River Conservation and Reclamation District. The District had run 52 cross-sections of the main lake and its tributary arms as part of the original survey of the reservoir site. Ranges run on the 1949 survey were located at or near the original cross-sections so that a check could be made on the elevation of the river channel at the time the lake was built. Usually the spud did not penetrate through the sediment in the river channel and it was necessary to interpolate its depth from the original cross-section nearest the range. Outside the river channel the spud readily penetrated to old soil. Approximate locations of cross-sections from both surveys are shown on the reservoir map (Fig. 6). The identifying numbers for the original cross-sections (e.g. 134-135) refer to the approximate distance of the cross-sections above the dam in thousands of feet, measured along the river channel.

The lake was more than 16 feet below spillway when the first 29 ranges were run in February 1949. Water in the channel was too shallow at that time for a boat to navigate above range 29, which is about 21

1/ Eakin, H.M., Silting of Reservoirs (Revised by Carl B. Brown) USDA Tech. Bull. 524, 1939.
2/ Tech. Letters of Sedimentation Section, Soil Conservation Service, USDA, 1938-40.

river miles downstream from the head of the lake. Measurements were taken in June 1949 on ranges 30 to 33 when the water level was less than 2 feet below spillway in order to obtain more complete data on the upper end of the lake. Some sediment was carried into the lake in May when inflow from the Brazos River was high, so sediment depths on ranges 30 to 33 are greater than they would have been in February. However, the amount carried in during this period is too small to have any effect on the sedimentation rates determined by a survey of this type.

Calculations. Standard formulae, as presented in the references under footnote 2, were used to calculate the original capacity and the capacity at date of survey as follows:

(1) For segments bounded by two ranges (e.g. seg. 2)
$V = 1/2(d_1 + d_2)A$

(2) For segments bounded by 3 ranges (e.g. seg. 3)
$V = 1/2(d_1 + d_2)A + \frac{d_3 w_3 h_3}{130,680}$

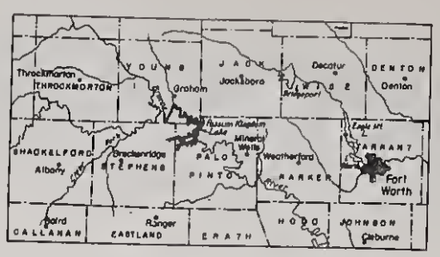
(3) For upstream segments bounded by only one range (e.g. seg. 4)
$V = 2/3\ (d_1)A$

(4) For the segment bounded by the dam and one range (seg. 1)
$V = d_2 \times A$

Where:

V = Volume of the segment, acre-feet
A = Area of the segment, acres
d_1 = Average depth on downstream range, feet
d_2 = Average depth on upstream range, feet
d_3 = Average depth on side range, feet
(for original capacity, d equals average original water depth; for capacity at date of survey, d equals average depth of water at time of survey)
w_3 = Width of side range from shoreline to shoreline, feet
h_3 = Perpendicular distance from side range to the point where the side channel intersects the thalweg of the main channel.

The segment areas were obtained by planimetering the areas between ranges on the shoreline map of the lake. The total planimetered area of the segments was about 1.5 percent smaller than the area of 20,600 acres computed by the Brazos River Conservation and Reclamation District. As their computations were made from a larger scale map showing more detail, the area of 20,600 acres was assumed to be correct, and the planimetered segment areas were adjusted proportionally to give the corrected total. The total original volume computed by this survey was 697,244 acre-feet, a variation of 4.7 percent from the capacity of 729,985 acre-feet computed by the District. As their computations were made by the contour method from a map with 10-foot contour intervals on a scale of 1 inch to 500 feet, the capacity they obtained is more accurate than one obtained by reconnaissance methods. Therefore, the original capacity of 729,985 acre-feet was taken as correct, and the sediment volume and total capacity at date of survey were adjusted accordingly. The percentage capacity loss was not affected by these changes in volume.



VICINITY MAP

LEGEND

- Lake Shoreline at Crest Level (Elev. 1000 Ft.)
- Approx. Location of Range and Range Number
- (27) Segment Number
- Brazos River Channel (Omitted in Lake Above Range 29)
- Tributary Stream Channel
- Hard Surfaced Road
- Secondary Road (Gravel or Unimproved)
- Railroad
- 19-91 Approximate Location of Cross-section Established by Brazos River C B R District

GRAHAM
To Newcastle
STATE HWY 24
To Jacksboro
STATE HWY 67
B.R.C.B.D.
BRAZOS RIVER
South Bend
To Breckenridge
END OF LAKE
Ming Bend
Wild Bend
Long Bend
Waco Bend
Carter Island
Costello Island
Gaines Bend
Hog Bend
Johnson Bend
STATE PARK EAST
STATE PARK WEST
Cedar Creek
JACK COUNTY
PALO PINTO COUNTY
YOUNG COUNTY
PALO PINTO COUNTY
STEPHENS COUNTY
PALO PINTO COUNTY
To Graford
To State Hwy 67
To Breckenridge and Caddo
To Caddo
To U.S. Hwy 180
STATE HWY 16
BRAZOS RIVER
N
6000 0 4000 8000 16000

Figure 6

POSSUM KINGDOM LAKE
PALO PINTO, YOUNG, AND STEPHENS COUNTIES, TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. BENNETT - CHIEF
REGION 4 CONSERVATOR - LOUIS P. MERRILL

REFERENCE: Modified from General Map of Lake Area by the Brazos River Conservation and Reclamation District

CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

DRAWN ARA — TRACED — CHECKED RER — DATE 3-17-49

4-R-7216

For In-Service Use Only

Range and Segment Data. Tabulations of the range and segment data and a summary table follow.

Table 3 - Range Data 1/ Possum Kingdom Lake

Range No.	Average Water Depth at Date of Survey 2/	Average Sediment Thickness	Average Original Water Depth
	Feet	Feet	Feet
1	44.6	1.9	46.5
2	34.9	1.2	36.1
3	35.9	2.2	38.1
4	38.5	1.7	40.2
5	48.5	0.4	48.9
6	31.0	0.5	31.5
7	52.6	2.6	55.2
8	36.7	0.0	36.7
9	24.7	0.4	25.1
10	46.5	2.6	49.1
11	38.7	0.9	39.6
12	49.1	3.2	52.3
13	49.7	0.3	50.0
14	46.2	1.5	47.7
15	46.5	2.1	48.6
16	49.9	2.9	52.8
17	48.3	2.5	50.8
18	55.2	3.3	58.5
19	48.1	2.5	50.6
20	29.8	1.8	31.6
21	23.5	1.3	24.8
22	28.2	2.1	30.3
23	26.5	3.0	29.5
24	26.1	4.7	30.8
25	22.8	4.1	26.9
26	22.3	5.1	27.4
27	17.7	8.3	26.0
28	13.8	8.9	22.7
29	13.1	7.4	20.5
30	9.2	9.1	18.3
31	9.3	6.7	15.9
32	7.3	8.5	15.8
33	8.0	7.0	15.0

1/ The average depths on each range were computed by totaling the recorded measurements on the range, and dividing these totals by the number of observations plus one (one is added to the number to take into account the ends of the range where the water depth is zero).

2/ Corrected to spillway level, 1000 feet. Lake stage varied between 983.6 and 997.6 feet during reconnaissance.

Table 4 - Segment Data - Possum Kingdom Lake

Segment No.	Surface Area 1/	Original Capacity	Capacity at Date of Survey	Sediment Volume	Capacity Loss
	acres	acre-feet	acre-feet	acre-feet	percent
1	82.04	4,799	4,529	270	5.6
2	343.14	18,718	17,723	995	5.3
3	335.69	17,588	16,661	927	5.3
4 2/	141.74	4,802	4,567	235	4.9
5	440.13	22,315	21,214	1,101	4.9
6	682.56	32,865	31,637	1,228	3.7
7	589.32	29,722	28,338	1,384	4.7
8 2/	130.55	4,354	4,328	26	0.6
9	421.47	19,367	18,502	865	4.5
10	872.78	38,708	37,180	1,528	3.9
11	1111.49	59,778	56,888	2,890	4.8
12 2/	428.94	13,254	13,168	86	0.6
13 2/	287.20	4,808	4,730	78	1.6
14	455.04	22,851	21,864	987	4.3
15 2/	1137.61	45,732	45,220	512	1.1
16 2/	786.99	16,535	16,275	260	1.6
17	484.88	21,019	20,147	872	4.1
18	1096.57	45,288	43,589	1,699	3.8
19	1063.00	39,437	37,630	1,807	4.6
20	1234.58	43,025	40,556	2,469	5.7
21	1290.52	36,393	34,392	2,001	5.5
22	2051.41	56,104	51,665	4,439	7.9
23 2/	469.96	9,498	8,840	658	6.9
24	492.34	14,844	12,949	1,895	12.8
25	365.52	10,545	8,937	1,608	15.2
26	380.44	10,329	8,579	1,750	16.9
27	253.63	6,772	5,073	1,699	25.1
28	496.07	12,079	7,813	4,266	35.3
29	141.74	3,062	1,906	1,156	37.8
30	234.98	4,559	2,620	1,939	57.5
31	205.14	3,508	1,898	1,610	45.9
32	257.36	4,079	2,136	1,943	47.6
33	399.09	6,146	3,053	3,093	50.3
34	1436.08	14,361	7,654	6,707	46.7
Total	20,600	697,244	642,261	54,983	
Corrected total 3/		729,985	672,420	57,565	

1/ Planimetered surface area of each segment was multiplied by the factor 1.01545 to adjust the area to the figure computed, by Brazos River Conservation & Reclamation District. See reservoir map (Fig.6) for segment locations.

2/ Segment located on an arm of the lake formed by a side creek.

3/ Original capacity computed by Brazos River Conservation & Reclamation District was 729,985 acre-feet. As this figure is more accurate than reconnaissance data, the total original, present, and sediment volumes were adjusted by multiplying them by the factor 1.046958.

Table 5 - Summary of Reconnaissance Sedimentation Data
Possum Kingdom Lake

	Quantity	Unit
Age 1/	7.75	years
Drainage Area Excluding Lake 2/	14,066	sq. mi.
Reservoir Data:		
Area, original and present	20,600	acres
Storage capacity at spillway elevation:		
Original	729,985	ac.-ft.
Present	672,420	ac.-ft.
Capacity per sq. mi. of drainage:		
Original	51.9	ac.-ft.
Present	47.8	ac.-ft.
Sedimentation:		
Total sediment	57,565	ac.-ft.
Average annual sediment accumulation	7,428	ac.-ft.
Per sq. mi. of drainage area	0.53	ac.-ft.
Per acre of drainage area	36	cu.-ft.
Sediment concentration 3/	0.501	percent
Depletion of Storage Capacity:		
Per year	1.02	percent
To date of investigation	7.89	percent

1/ Storage began May 1941. Date of investigation, Feb. 1949.
2/ Includes 1111 sq. miles drainage above lakes in the watershed. Excludes 8950 sq. miles of non-contributing drainage area at the head of the watershed.
3/ Based on sediment load at South Bend gaging station for the period Jan. 15, 1942 to Sept. 30, 1948.

Sediment Types and Distribution

Types of Sediment. In the larger part of the reservoir the sediment is chiefly silt and clay ranging from light tan to dark brown in color. Some fine brown sand occurs in small areas where the slopes adjacent to the lake are sandy soil, principally on ranges 3, 4, 20, and 21. It overlies a valley bottom soil of brown clay loam, light brown gravelly clay, or light brown sandy loam. The distinction between lake sediment and valley soils is good except in the areas of brown sandy loam soils, where the only distinction is frequently a difference in texture. Ranges 30 to 33 near the head of the lake were measured in June shortly after high flows on the Brazos had filled the lake. The top of the sediment was so nearly fluid that the sounding weight when not supported would settle 2 feet or more into the fine silt and clay. Therefore, in making water depth measurements with the sounding weight and line, the top surface of sediment was recorded as the first point where contact of the weight on sediment could be felt on the line.

Distribution of Sediment. The small arms of the lake extending into tributary creek valleys generally contain much less sediment than was found in the main body of the lake. Segments 4 and 23 are the only ones which show sediment nearly comparable in amount to the adjacent sections in the main lake. Sediment in the main lake below range 24 is confined chiefly to the channel, averaging 12 feet deep in the channel and about 0.3 foot in the old valley flat. Above range 24, sediment in the channel is 14 to 27 feet deep and generally more than 1 foot deep on the narrow flats outside the channel (see Figs. 7 & 8). It is the area of greatest sediment deposition, and the capacity of the lake above this range is decreasing at an extremely high rate (see Fig. 9), with the exception of the uppermost segment, which is subject to frequent scour when high flows occur on the river with the lake at a low level.

Table 6 shows the amount of sediment in various sections of the lake, the proportion of the total sediment in each section, and relationships to the original storage capacity.

Sedimentation Rate and Sources of Sediment

Rate of Sedimentation. This reconnaissance shows that Possum Kingdom Lake has been trapping sediment at a rate of 7428 acre-feet annually and losing 1.02 percent of its original capacity each year. Some additional sediment has also been passing through the lake. Suspended sediment sampling of water passing the dam has been maintained since January 1942, the sediment concentration determined, and sediment volumes computed. 3/ These data show the average annual discharge of water from the lake from January 15, 1942 to October 1, 1947 has been 702,270 acre-feet and the average percentage of sediment by weight, 0.017.

3/ Bloodgood, D. W. and Stout, I. M., The Silt Load of Texas Streams, Part IX, USDA, Irrigation Division and Texas Board of Water Engineers, August, 1948.

Figure 7. Sediment about 6 feet deep on old valley of Ming Bend in upper main body of Possum Kingdom Lake in December, 1943, 2½ years after storage began. Lake stage is 22 feet below spillway.

Figure 8. Approximately 4½ feet of sediment nearly cover an old oil field meterhouse. Same area and date as Figure 7, above.

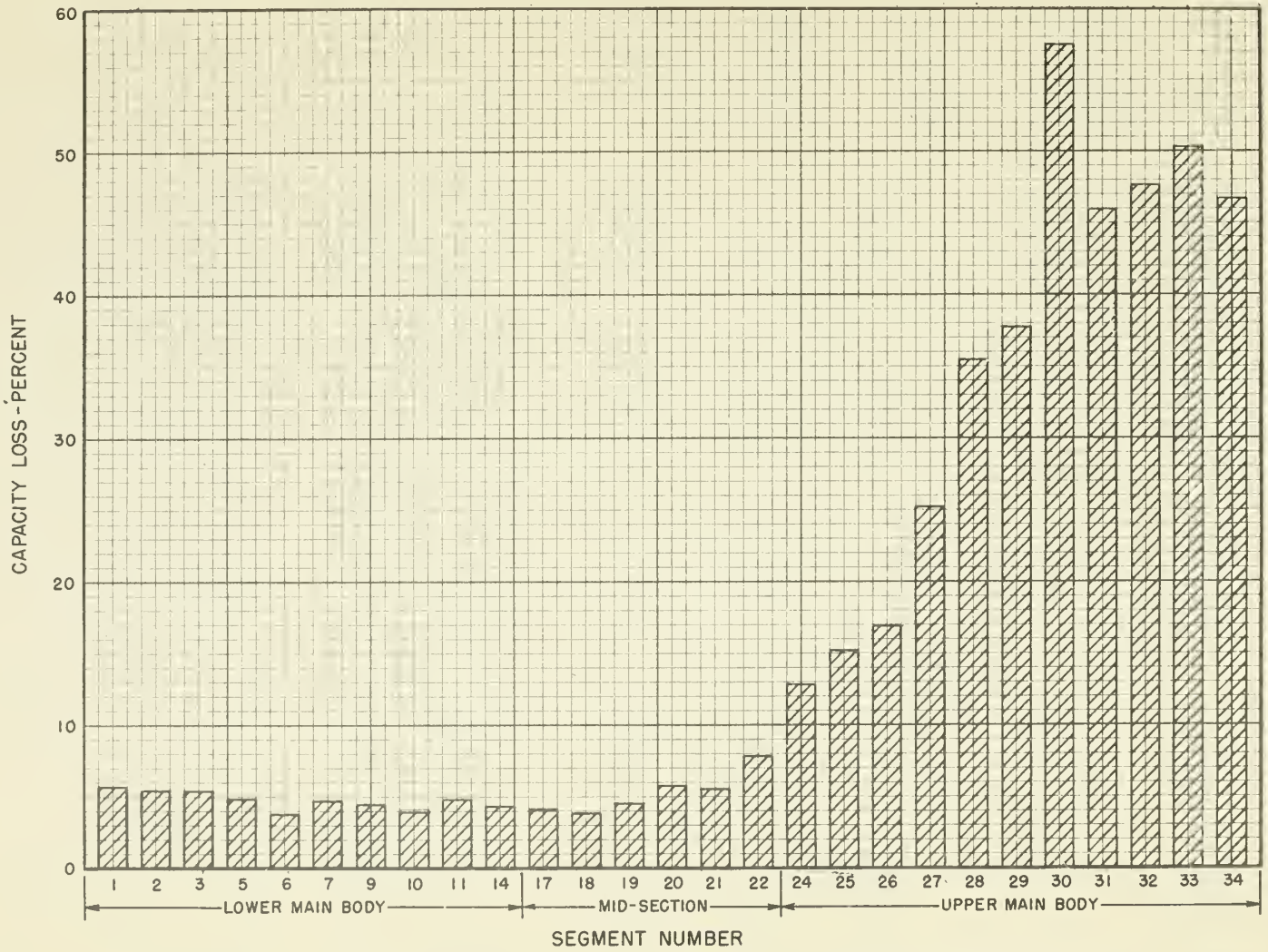


Fig. 9 CAPACITY LOSS OF SEGMENTS IN POSSUM KINGDOM LAKE
(Excluding Tributary Bays)

Table 6 - Distribution of Storage Capacity and Sediment in Possum Kingdom Lake

Section	CAPACITY			SEDIMENT	
	Original	Proportion of Orig. Capacity	Reduction in Capacity	Volume at Date of Survey	Proportion of Total Sed.
	ac.-ft.	percent	percent	ac.-ft.	percent
Lower main body, seg. 1,2,3,5,6, 7,9,10,11, 14	279,235	38.25	4.56	12,747	22.14
Mid-section seg. 17,18, 19,20,21, 22	252,595	34.60	5.51	13,911	24.17
Upper section, seg. 24-34 incl.	94,524	12.95	30.64	28,965	50.32
Side arms seg. 4,8, 12,13.15, 16,23	103,631	14.20	1.87	1,942	3.37

This amounts to 135 acre-feet of sediment [4] passing through the lake each year. Therefore the total annual sediment contribution to Possum Kingdom Lake has been 7563 acre-feet, which is equivalent to 0.54 acre-feet per square mile of contributing drainage area. The amount of sediment carried past the dam is equal to 2 percent of the sediment carried into the lake, so the trap efficiency of Possum Kingdom Lake is 98 percent.

Garin [5] predicted, from a study of applicable stream flow and silt load records before the dam was completed, that the annual sediment load to Possum Kingdom Lake would be 6842 acre-feet and 6550 acre-feet of sediment would be deposited annually. These estimates are 10 percent and 12 percent lower, respectively, than the amounts determined from this reconnaissance. From interpolated stream flow records he estimated the average annual flow into the lake would be 1,000,000 acre-feet while it has probably averaged about 900,000 acre-feet annually since the dam was constructed. His estimate of sediment volume

4/ Assuming 1 cubic foot of sediment weighs 55 pounds.
5/ Garin, Alexis N., Advance Report on the Economic Effects of Predicted Sedimentation in Morris Sheppard Lake, Texas, SCS-EC-3, December 1941.

was computed on the basis of 70 pounds of suspended load to the cubic foot of deposit, which is too great a figure in the writers' opinion for the weight of sediment in Possum Kingdom Lake. Use of a smaller figure for weight per unit of volume would have resulted in a correspondingly higher sediment volume estimate, which would compare even more closely to the sedimentation rate determined by this reconnaissance. For example, if the average percentage of silt by weight which he determined is used (0.764), and 55 pounds taken as the weight of 1 cubic foot of sediment, then 1 acre-foot of water would contain 0.008668 acre-foot of sediment. Using 900,000 acre-feet per year as the average stream flow, the amount of sediment entering the lake would be 7801 acre-feet annually as compared to 7563 acre-feet determined by this survey, a difference of only 3 percent. However, Garin's estimates are exceptionally accurate, considering the large number of assumptions which had to be made at that time.

Expected Life of the Reservoir. If sediment deposition in Possum Kingdom Lake continues at its present rate it will be completely filled with sediment in 98 years. If its storage capacity is not sufficient to meet the water requirements for power production when reduced by 70 percent, then its effective life would be 69 years under present conditions. Several actions have been considered by various agencies which would decrease the quantity of sediment entering the lake if put into effect, thus increasing its life. One is the construction of a large reservoir on the Brazos near Aspermont. Another is the installation of a comprehensive Flood Control Program in the Brazos River Watershed by the Soil Conservation Service. Continued expansion of the Soil Conservation District program in the watershed will be effective to some extent. The construction and enlargement of small municipal water supply reservoirs in the watershed which is taking place will also decrease the sediment load of the Brazos by a small amount. The evaluation of these factors and their net effects on the life of the lake is beyond the scope of this report, but their total effect would be great and could increase the lake's useful life by 50 percent or more.

Sediment Sources. In the Palo Pinto section which surrounds the reservoir, the rates of sediment output in the various tributary drainages vary widely because of sharply contrasting differences in types of soils and resistance to erosion of underlying formations. On the average, however, the rates of sediment output in the Palo Pinto section are relatively low, and it is estimated that 75 percent of the sediment carried by the principal streams originates by sheet erosion. For the section as a whole it is estimated that the average rate of sediment production is somewhat less than the figure for the entire drainage area of Possum Kingdom Lake (0.5 acre-foot per square mile annually).

The average rate of sediment output for the Redbeds Plains section is substantially above the average for the total drainage area, and it ranges from about 1.0 to 2.0 or more acre-feet per square mile annually. Therefore it is estimated that substantially more than 50 percent of the sediment deposit in the reservoir originated in the Redbeds Plains. Since gully development is serious, it is believed that about 75 percent of the sediment originates by gully development and channel bank erosion and 25 percent by sheet erosion.

The small area and resistant rock formations of the Edwards Plateau section cause it to be a negligible source of sediment. Furthermore the remoteness of the High Plains and relatively coarse texture of sediment in streams flowing from it prevent the High Plains from being any more than a minor source of sediment to Possum Kingdom Reservoir.

Summary

1. The original capacity of Possum Kingdom Lake was 729,985 acre-feet, and its surface area 20,600 acres. The total cost of the dam and power plant projects was approximately $8,655,000.

2. In February, 1949 the capacity of the lake had decreased to 672,420 acre-feet due to sediment accumulation. This is a capacity loss of 57,565 acre-feet in 7.75 years, or 7,428 acre-feet annually. The total capacity reduction amounted to 7.89 percent to February, 1949 or 1.02 percent annually. The surface area of the lake has remained substantially the same.

3. About 135 acre-feet of sediment passes over the spillway and through outlets annually, amounting to 2 percent of the total sediment entering the lake each year. The amount of sediment entering the lake annually is equivalent to 0.54 acre-foot per square mile of contributing drainage area. If deduction of the total drainage areas of the small upstream reservoirs (1,111 square miles) is made, then the total net drainage area of Possum Kingdom Lake is 12,955 square miles and the average annual sediment contribution to the reservoir is 0.57 acre-foot per square mile.

4. If the present sedimentation rate continues the lake will be completely filled with sediment 98 years from the time it was constructed, and its effective life will be 69 years, based on a capacity loss of 70 percent . Application of a combination of feasible sediment control measures may increase the life of the lake by 50 percent or more.

5. It is believed that the figures in this report on percentage of capacity loss, volumes of water and sediment, and contribution of sediment per unit area of drainage have a higher order of accuracy than those of the usual reconnaissance survey. The investigation had the advantages of access to good original maps and well-distributed cross-sections. More than the usual number of measurements were made. Also a 6-year record of suspended sediment measurements at the dam was available. The figures on volumes of sediment and water probably are accurate within 10 percent or less. Any future surveys should be made on the original cross-sections with instrumental control of sounding locations.

Acknowledgments

Personnel, data, maps, and equipment were made available by Mr. R. D. Collins, General Manager of the Brazos River Conservation and Reclamation District, Mineral Wells, Texas for use on the survey.